The Osmotic Pressure of Solutions of Cane Sugar in the Vicinity of Four Degrees Centigrade

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DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

BY

PAUL B. DUNBAR

BALTIMORE

1907

EASTON, PA.:
ESCHENBACH PRINTING COMPANY.
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The Osmotic Pressure of Cane Sugar Solutions in the Vicinity of Four Degrees Centigrade

INTRODUCTION.

The present series of measurements is a continuation of the work which has been carried on in this laboratory for the past six years on the direct measurement of osmotic pressure. The difficulties which have been met and overcome, as well as the various steps in the development of the present method of measurement, have been fully recorded in the published accounts of the work which have appeared from time to time. As the method used in the present work is similar in all essential respects to that which has already been described, reference will be made to the original articles of Morse, Frazer and their co-workers for the details of the process.[1]

The results of the measurements made during the last two years led Morse and Frazer to sum up their conclusions in the following rule: "Cane sugar, dissolved in water, exerts an osmotic pressure equal to that which it would exert if it were gasified at the same temperature and the volume of the gas were reduced to that of the solvent in the pure state."[2] All the measurements upon which this conclusion was based were carried out at a temperature in the vicinity of 20° C.

In the last article published on the subject in 1906,[3] the intention was expressed of extending the work upon cane sugar by taking up the measurement of pressure in the vicinity of 0°. This intention was carried out during the present year.[4] It was then found that cane sugar in the vicinity of 0° fails to conform with the rule just given and exerts a pressure somewhat in excess of the calculated gas pressure. It may

[1] Amer. Chem. Jour., **26**, 80; **28**, 1; **29**, 173; **34**, 1; **36**, 1, 39; **37**, 324, 425.
[2] *Ibid.*, **34**, 93.
[3] *Ibid.*, **36**, 87.
[4] *Ibid.*, **37**, 425.

be mentioned here that the measurement of glucose was also undertaken, and at 20°,[1] a pressure conforming with the rule just stated was exhibited, but at 0°,[2] the same kind of abnormality was manifested that is shown by cane sugar. In both cases, the deviations from the rule were quite analogous to the deviations of the observed molecular depressions of the freezing points from the calculated value, 1.85.

Because of this divergence of the osmotic pressures of both cane sugar and glucose from the calculated gas pressures at 0°, and their agreement at 20°, it was thought desirable to measure the pressures of these solutions at various points between 0° and 20°. It was believed that the method of measurement was sufficiently accurate to determine with certainty (1) whether there is a temperature between 0° and 20° at which the osmotic pressure, like the volume of the solvent, is at a minimum and from which it increases, with change in temperature, in both directions; (2) whether osmotic pressure, unlike gas pressure, has little or no temperature coefficient, as might be inferred from the fact that the pressures at zero are, in general, nearly equal to those observed in the vicinity of 20°; or, finally, (3) whether the abnormality found to exist at 0° gradually and uniformly disappears with rising temperature, until the osmotic pressure of the solutions are in agreement with the gas pressures. It was for the purpose of deciding this question that the present series of measurements was undertaken. Four degrees was taken as the temperature at which the first intermediate series should be made, principally because it was easy, during the winter months, to maintain this temperature quite effectively in the constant temperature bath used in the experiments. Moreover, since 4° is approximately the temperature of maximum density of the solvent this temperature suggested itself as the most promising point to begin the work.

Constant Temperature Bath.

The details of the constant temperature bath used in these

[1] Am. Chem. Jour., **37**, 357.

[2] F. M. Rogers, Dissertation, Johns Hopkins University, 1907.

experiments need not be given here, as it has been fully described in a preceding article.[1] Briefly, it consists of a rectangular wooden box, 1.23 meters long, 0.45 meter wide and 0.65 meter deep, lined with copper and carefully protected from external heat and loss by radiation. The capacity of the tank is about 300 liters. The air space above the tank is 0.5 meter high, 0.45 meter wide and about 0.92 meter long, and is similarly protected. Both the water and the air in the enclosed space above it are kept in constant circulation by means of small propellers driven by a motor located outside the bath.

The device for maintaining the uniform temperature of about 4° requires more detailed description. In this work, of course, the elaborate arrangements of electric thermostats and stoves which were used very effectively in the measurements at 20° were of no value and were consequently removed. No precautions were taken to maintain a uniform temperature in the room outside the bath.

The desired temperature was maintained in the bath by means of a system of brass pipes which lines the top and sides of the air space and extends a short distance into the water of the tank below. Through this system a stream of water is kept constantly flowing. The water used for this purpose is drawn from a two-inch pipe connected directly with the street main and without any outlet below the third floor, where the bath is located. This insures that the water, when it enters the bath, is very little warmer than when it enters the building from the street main. It has been found that under the most unfavorable conditions, the temperature of the water as it enters from the street is not more than 0°.5 below that in the pipes of the cooling device. After making the circuit of the system the water passes out of the bath and is carried away by a drain pipe.

The system is made of sections of brass pipe of 14 mm. internal and 21 mm. external diameter, running parallel to each other, connected by "returns" in such a way that the

[1] Am. Chem. Jour., **36**, 2.

distance between adjacent pipes is about 50 mm. and the height of each return coupling about the same. The system is made in three sections, which are connected by flexible hose couplings. The largest of these sections consists of 34 vertical pipes each 0.7 meter long, connected by return couplings and firmly clamped to the back and sides of the air space. This section extends upward almost to the top of the bath and descends into the water below about 0.3 meter. The supply pipe is connected with this section at the left of the bath. The second section consists of twelve vertical pipes each 0.3 meter long, also connected by returns. It is designed to occupy the front of the air space just behind the hinged plate glass window. It is suspended from the top of the bath by two hooks and can be disconnected and removed when it is desired to open the bath for the purpose of introducing the cell and manometer. To prevent interference with reading the height of mercury in the manometer, strips of raw hide are passed through holes in each end of the bath and tied to the second section. By means of these, any pipe interfering with the view of a manometer can be readily displaced to one side or the other in the vertical plane. The third section consists of eight pipes, 0.8 meter long, connected as in the preceding cases and extending lengthwise of the bath. This section is attached to the hinged top of the bath by hooks and is connected with the waste pipe. The rate of flow of the water through this coil is regulated at will by a ball valve. There is thus obtained a continuous line of pipes about 44 meters long, forming a kind of bottomless cage or box, conforming to the top and sides of the bath. The portion of the pipes in the air space have a cooling surface of about 2 square meters, while the surface of the walls and top of the air space itself is about 1.8 square meters. The portions of pipe immersed in the water of the tank have a surface of about 0.33 square meter, while that of the tank is about 2.32 square meters.

Temperature Conditions.

With this apparatus, the temperature varied within sur-

prisingly small limits from February 7th until March 19th, during which time most of the measurements here recorded were made. The essential conditions are that the fluctuations of temperature in the bath shall not be rapid enough, during any one experiment, to produce "thermometer effects"[1] in the cells, and that any given series of measurements shall be carried through at approximately the same temperature. During seasons of moderately uniform mean daily temperature, as in the winter, these conditions may be maintained by a judicious regulation of the flow of water through the pipes, but during seasons of continuously rising or falling mean temperatures, as in portions of spring and autumn, a further expedient is necessary, both to avoid "thermometer effects" and to secure a period of fairly uniform temperatures sufficiently prolonged to permit the completion of a series of measurements. At such times, boxes of ice are placed in the bath, both in the water and in the air space above, and a constant level siphon is provided to drain off the overflow from the melting ice. In this way, by carefully regulating the quantities of the melting ice and the rate of flow of the water, it is possible to secure moderately uniform temperatures for a long time, despite unfavorable conditions.

How well these conditions were maintained may be seen in Table I., which shows the mean temperatures of the water in the tank as well as the extreme variation in temperature during each measurement:

Table I.

Mean bath temperature.	Extreme variation.
4°.84	0°.8
4°.93	0°.8
4°.58	0°.6
6°.05	0°.7
4°.50	0°.15
4°.50	0°.15
4°.48	0°.9
4°.51	0°.7
4°.34	0°.5

[1] Am. Chem. Jour., **34**, 23, 92; **36**, 1.

Table I.—Continued.

Mean bath temperature.	Extreme variation.
5°.23	0°.5
5°.03	0°.5
6°.05	0°.7
4°.35	0°.3
4°.55	0°.35
4°.48	0°.75
4°.33	0°.15
4°.33	0°.1
5°.23	0°.5
4°.60	0°.7
4°.32	0°.35

It will be seen that the highest temperature recorded is 6°.05 and the lowest, 4°.32, while the greatest fluctuation during any one measurement was 0°.9. The efficiency of the cooling apparatus can hardly be judged by the highest temperature recorded, since this is an extreme case, due probably to a temporary neglect of proper regulation of the flow of hydrant water. It will be seen that the nearest approach to it is 5°.23, which is 0°.82 lower, while the mean temperature of all measurements was 4°.76. The mean variation for all measurements is only 0°.51, so that 0°.9, the highest variation recorded, is also somewhat misleading. All the temperatures recorded in Table I., except the fifth and sixth, were maintained by means of the hydrant water apparatus alone. In the case of the two exceptions, the bath was cooled by melting ice. These measurements, which are recorded in Tables VI. and VII., were begun at 12.00 M., April 2nd, and continued until 2.30 P.M., April 3d. During this time, a mean temperature of 4°.50 was maintained with a variation of only 0°.15.

It was to be expected that the temperature of the air space would vary much more widely than that of the water in the tank, since it would be influenced to a greater degree by fluctuations in the temperature of the room outside. This is not a serious fault, however, since its only effect is to cause the air in the manometer to expand or contract with the rise or fall in temperature without influencing the actual pressure.

It will be observed in the records of the individual experiments that in most cases where a reading was made within a few hours of the setting up of the cell, the temperatures of the water and air in the bath are somewhat high. This is the result, of course, of opening the bath in order to insert the cell. Since the temperature of the room outside is higher than that of the bath, there is a rise in temperature in the latter, and several hours usually elapse after closing the bath before equilibrium is restored. In most cases, these elevated temperatures were omitted in calculating the averages for Table I.

Manometers.

The manometers known as Nos. 5, 6, 11 and 13 were used in this work. Their form and method of preparation have been fully discussed in a preceding article.[1] The calibration data employed by former workers were used in calculating the pressures registered by these manometers, but a careful re-determination of their air volume was made by Frazer and Lovelace shortly before the work was begun.[2] It was found that the air volumes had diminished respectively by 1.66, 1.29, 1.68 and 1.80 per cent of the original volumes. This loss is believed to be due to the action of the oxygen of the air on the impurities in the mercury. This fault will be guarded against in the future by filling the manometers with nitrogen instead of air and by taking even greater precautions than heretofore to obtain pure mercury.

All the manometers that have been used in the osmotic pressure measurements have been provided with a slight enlargement of the tube at its open end, where it is inserted in the glass tube of the cell. When the manometer is pushed upward under pressure, this enlargement presses outward the rubber stopper by which the manometer is secured in the cell, and the increased resistance tends to prevent further upward movement. As a further measure against this danger, manometers 6 and 11 have been provided with a second enlargement at such a distance above the first that it falls inside

[1] Am. Chem. Jour., **36**, 21.
[2] *Ibid.*, **37**, 326.

the rubber stopper when the latter is adjusted. The stopper is then securely wrapped with "waxed end" and the second enlargement acts as a support to prevent the slipping of the manometer through the stopper.

Cells.

Cells B and I were used in most of the measurements recorded. B had previously been used in the measurement of cane sugar and glucose at 0° and had shown itself trustworthy for concentrations up to and including 0.7 normal. It was, therefore, used interchangeably with I for all measurements up to this concentration. I is also an old cell which has been used in former measurements, but owing to a leak which developed in the joint between the cell and the glass tube, it became necessary to take it apart and subject it to a process of renovation.[1] It was thereafter put together like a new cell and treated to the usual preliminary cleansing and membrane-forming processes.[2] It soon showed itself capable of withstanding pressures of concentrations up to normal, and was therefore used in measuring all the more concentrated solutions where it was deemed inadvisable to use B.

Two of the measurements recorded were made with H. This cell had been subjected to the same renovation process as I, but it proved untrustworthy for all but dilute solutions. Almost at the end of the work, I was unfortunately put out of service by the breaking of the glass tube into which the manometer is inserted. Cells D and G, which had previously been used in the measurements at 0°, were therefore used each for one measurement.

Deposition of Membranes.

The membranes, as heretofore, consist of copper ferrocyanide deposited electrolytically.[3] The deposition of the membranes was carried out in a bath of running water as a

[1] Amer. Chem. Jour., **37**, 325.
[2] *Ibid.*, **36**, 28.
[3] *Ibid.*, **36**, 29.

precaution against cracking the cell or loosening the membrane by too sudden changes of temperature on introducing it into the constant temperature bath. The solution to be measured, as well as the copper sulphate solution which surrounds the cell during a measurement, was likewise cooled in running water to the temperature of the bath, for the same reason, and also to insure a more rapid establishment of equilibrium between the temperature of the bath and that of the solution in the cell.

Material.

The cane sugar used was the purest grade of rock candy, pulverized and dried over calcium chloride to constant weight. As a test of its purity, the rotation of a standard solution was measured in a Schmidt and Haensch half-shade saccharimeter. The standard solution for this instrument contains 26.077 grams of sugar in 100 cc. of solution at 20° and produces a rotation of 100° when polarized in a two-decimeter tube. Such a solution was prepared and found to cause a rotation of 99°.96.

The solutions were made up on the weight normal basis, taking H as 1.00, and they covered the usual range of ten concentrations from 0.1 normal to normal. All weights were corrected for air displacement.

Toward the end of the series of measurements some fear was felt that the cells might become contaminated with *penicillium glaucum*, as in the past year.[1] Accordingly, from this time on, all solutions were made 0.001 normal with thymol.

Membrane Formers.

As a means of repairing breaks in the membrane, all sugar solutions are made one-hundredth ion normal with respect to potassium ferrocyanide. The amount of ferrocyanide needed to form such a solution is calculated on the assumption that potassium ferrocyanide dissociates completely into five ions at this dilution and therefore a one-hundredth ion normal solution should contain a number of grams of ferro-

[1] Amer. Chem. Jour., **36**, 34, 37.

cyanide equal to one five-hundredth of its molecular weight per 1,000 grams of water.

For the same reason, the cell is surrounded by a one-hundredth ion normal solution of copper sulphate made up by dissolving one two-hundredths of a gram molecular weight of copper sulphate in 1000 grams of water. In the case of the copper sulphate also, it is assumed that dissociation is complete at this dilution.

Precautions against Dilution.

The method of inserting and securing the manometer in the cell preparatory to a measurement has not been changed, nor has the process of taking down a cell at the conclusion of a measurement been altered.[1] The following addition, however, has been made to these operations: During the process of rinsing and filling the cell with the solution to be measured, it is repeatedly dipped in a sugar solution of roughly the same or slightly greater concentration. The tubes of sheet rubber with which the cell is always protected while being handled is also wet with the solution. After the process is completed, the rubber tube is removed and the dipping solution washed off by repeated rinsing with a portion of the same copper sulphate solution with which the cell is surrounded during the measurement. Just before it is taken down, after completing the measurement, the cell and also the protecting rubber cap are again dipped in the sugar solution.

It is believed that this process partially prevents dilution of the cell contents during the operation of setting up and taking down the cell. As will be explained later, it is now believed that the correction for the dilution of the cell content, which should be applied in calculating osmotic pressure, is larger than at first supposed, while that due to inversion is correspondingly smaller. Any process which will prevent this dilution will accordingly increase the trustworthiness of the results. The causes of this dilution have been fully discussed in former papers.[1] They are principally: 1, the

[1] B. S. Hopkins, Dissertation, Johns Hopkins Univ., 1906.
[2] Amer. Chem. Jour., **36**, 26, 48; **37**, 327, 459.

slipping of the manometer in the stopper, or the crowding upwards of both manometer and stopper when the former cannot slip in the latter; 2, the sucking in of water from the cell wall while the cell is being closed for a measurement, and again while it is being taken apart after an experiment. The method of securing the manometer in the cell has been so far improved that the displacement of the manometer and the distortion of the rubber stopper have been greatly reduced. So much so, in fact, that these are no longer of much importance as sources of dilution of the contents of the cell. In Series II. of the cane sugar measurements,[1] the average slipping of the manometer was 0.95 mm., while in the present series, it has been reduced to 0.25 mm., as will be seen in Table XXII. The mean loss in rotation in Series II. was 2.8 per cent, while in the present series, the mean loss was only 1.28 per cent. This decided decrease in the amount of loss in rotation is certainly due, in part, to the above improvements in manipulation, although another improvement, to be mentioned later, probably contributed even more to this result.

The second cause of dilution—namely, the sucking in of water from the cell wall during the processes of closing and opening the cell—is, however, still a serious factor. On completing the deposition of the copper ferrocyanide membrane, the cell which is to be used for a measurement is well rinsed with distilled water. The cell walls are, therefore, thoroughly impregnated with water. The next step in the setting up process is to rinse the cell repeatedly with the solution to be measured. This displaces the water on the interior of the cell with solution, but at the same time the solution is osmotically active and is drawing in water from the cell wall, thereby diluting itself. This dilution continues until the mouth of the cell is closed by the stopper bearing the manometer and counter pressure is brought to bear against the osmotic pressure by tightening on the nut by which the manometer is secured to the cell. Even after the closing opera-

[1] Am. Chem. Jour., **36**, 53.

tion is complete, dilution will continue until the maximum pressure is reached, but the latter dilution is probably slight compared with the former, owing to the fact that a large initial pressure is immediately brought upon the solution by mechanical means.

Similarly, during the process of opening the cell, serious dilution may occur as soon as the pressure of the nut is released, since the cell wall is now saturated with the copper sulphate solution, and especially, since, during the opening of the cell, the solution is constantly under considerably diminishing pressure.

If, however, the water in the cell wall is surrounded by an osmotically equivalent solution, such as is used in the dipping process, there is a tendency toward establishing a condition of equilibrium during the opening and closing processes, and danger of dilution is diminished.

Correction for Loss in Rotation.

This leads to a discussion of the relative importance of corrections for dilution and for inversion. These corrections are based on the loss of rotation observed in the solution after removal from the cell. In the earlier measurements made in this laboratory, the corrections were made on the assumption that all loss in rotation was due to inversion, although it was realized that a part was certainly due to dilution. The dilution, however, was believed to be smaller than it subsequently proved itself to be.[1] Efforts to determine the amount of invert sugar in the solutions taken from the cell by the method of Fehling gave uncertain results which were always much lower than were to be expected if the assumption concerning the loss of rotation were correct. This was one of the facts which led to a modification of the earlier view regarding the relative importance of inversion and dilution.

If dilution is really the main cause of the loss in rotation, two obvious methods for lessening it suggest themselves.

[1] Am. Chem. Jour., 36, 42.

One is the dipping process just described, and the other is to carry on the manipulation of closing and opening the cell with the greater possible rapidity. The attempt was made in the present work to hasten these operations as much as possible without endangering the cell and manometer. It was found that almost invariably the loss in rotation increased with the time consumed in closing and opening the cell, and that a delay in opening the cell caused a more marked loss than a delay in closing it. This is to be expected, since in taking down the cell its contents are under constantly diminishing pressure and consequently there is increased opportunity for dilution. In closing the cell, on the other hand, the cell contents are under constantly increasing pressure and the chances for dilution are correspondingly less. The usual percentage loss in rotation was also considerably diminished after introducing the dipping process. The mean loss in rotation in the present series was 1.28 per cent. In the last series with glucose at 20°,[1] the loss was 1.49 per cent, while in the series with glucose at 0°,[2] it was only 0.9 per cent. Now in the case of the glucose there can be no possibility of inversion. These facts furnish qualitative evidence of the correctness of the assumption that most of the loss of rotation is due to dilution.

It is evident that only that dilution which takes place during the setting up process can have any effect on the measurement. But at present no means are at hand for determining what proportion occurs at the beginning and what at the end of the operation. It has consequently been assumed that one-half of the dilution has occurred at the beginning of the measurement and one-half at the end. As a matter of fact, there is reason to believe that more than half the dilution occurs during the opening of the cell, since, as has been explained, the cell contents are then under constantly diminishing pressure.

The pressures in the following tables have therefore been calculated in three ways:

[1] Amer. Chem. Jour., **37**, 330.

[2] F. M. Rogers, Dissertation, Johns Hopkins University, 1907.

(1) The observed pressures without correction for loss in rotation are given.

(2) The observed pressures have been corrected on the assumption that all loss of rotation is due to inversion.[1] These results are probably too low, but they have been inserted for the sake of comparison with former measurements, all of which have been corrected in this way.

(3) All loss in rotation has been ascribed to dilution, but the pressures have been corrected for only one-half of this. This method is believed to be the fairest way of correcting for loss in rotation.

A fact has been observed in the measurements at 0° which tends to confirm this belief.[2] It is that in all but the more concentrated solutions the ratio of the observed freezing point lowering to the theoretical lowering, 1.85, is very nearly equal to the ratio of the observed osmotic pressure corrected for one-half dilution to the theoretical gas pressure.

It is, of course, not to be supposed that no inversion whatever occurs in the cell, but there is no method which seems to be satisfactory for determining with exactness its amount, and everything goes to show that in any case it is small compared with the dilution. In fact the evidence obtained by the method of Fehling[3] indicates that, as a correction, the amount of inversion would not exceed 0.05 of an atmosphere for the most concentrated solution measured.

Measurements without Membrane Formers.

It will be observed that the molecular osmotic pressures of the 0.1 normal solutions are in both cases higher than the molecular pressures of the next five concentrations, whereas it would be expected that these should be the lowest of the series. The high results in the case of the 0.1 normal solutions may be ascribed to the fact that any constant error or accumulation of errors would have proportionally the greatest effect on the least concentrated solution.

[1] Amer. Chem. Jour., **36**, 42.
[2] *Ibid.*, **37**, No. 6.
[3] *Ibid.*, **34**, 31.

One of the largest of these constant errors lies in the possibility that the small amounts of membrane formers which are dissolved in the solution to be measured and in the water surrounding the cell for the purpose of repairing breaks in the membrane, are not exactly osmotically equivalent. As has been stated, it is assumed that at the dilution used in the work, both of the membrane formers are completely dissociated. Moreover, the further assumption is made that potassium ferrocyanide dissociates into five ions, whereas the work of Jones and Bassett[1] furnishes some evidence that it dissociates into eight ions. If this be the case, the ferrocyanide solution, as at present made up, will have a somewhat greater ionic concentration than the copper sulphate solution, and should therefore exert a somewhat greater pressure. Some work has been done on this subject, but the evidence is not final. It has been found, however, that solutions of the membrane formers alone, when set up under the usual conditions, exert a slight pressure in the direction of the ferrocyanide, amounting to from 0.05 to 0.10 atmosphere.

In the hope of eliminating this source of error, a 0.1 normal sugar solution was set up with cell H without the use of membrane formers. It was found that under these conditions leaks in the membrane developed so that it was impossible to secure a measurement.

Cells B and I were then set up with 0.1 normal sugar, using one-half the usual quantities of membrane formers. The results were somewhat more satisfactory here, pressures of 2.29 and 2.31 atmospheres being registered by the two cells respectively. But a comparison of these results with those of the more concentrated solutions lead to the belief that they are probably too low.

It, therefore, seems probable that it will be impossible with the present methods of measurement to support pressure in the cells without the use of some membrane formers. It is a curious fact that in the case of the solutions in which one-half the usual quantity of membrane formers were used no

[1] Amer. Chem. Jour., **34**, 311.

loss of rotation was observed in the solution after removal from the cell. In such dilute solutions, however, the rotation of the fresh solution is only 12°.7, so that a loss in rotation of 0.5 per cent would amount to only 0°.06, which might easily be overlooked. For this reason no particular significance is attached to the fact.

Table II.

Original wt. normal concentration of solution, 0.1.
Rotation of original solution, 12°.55 at 20° C.
Rotation at conclusion of exp't, 12°.45 at 20° C.
Loss in rotation, 0°.1 = 0.8 per cent.
Calibration units of air in manometer, 434.98.
Time of setting up cell, 4.15 P.M., Feb. 14, 1907.

Experiment No. 1.
Manometer used, No. 5.
Capillary depression, 0.02.
Cell used, H.
Resistance of membrane, 219,000.
Initial pressure, 2.15 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
Feb. 14.											
9.00 P.M.	(5°.4)	6°.95	156.02	152.14	1.00	0.48	0.01	0.02			
Feb. 15.											
10.00 A.M.	4°.95	5°.9	153.20	149.96	1.00	0.48	0.01	0.02	2.39	2.27	0.12
1.00 P.M.	4°.6	6°.0	153.57	150.26	1.00	0.48	0.01	0.02	2.39	2.26	0.13
5.10 P.M.	4°.5	5°.9	153.61	150.36	1.00	0.48	0.01	0.02	2.38	2.26	0.12
Feb. 16											
10.30 A.M.	5°.3	6°.3	153.49	150.03	1.00	0.48	0.01	0.02	2.39	2.27	0.12
	4°.84		Displacement of manometer = 0.4 mm.						2.39		

Correction, if all loss in rotation is ascribed to inversion = 0.01 atmosphere.
Osmotic pressure = 2.39 atmospheres.
Molecular osmotic pressure = 23.88.
Molecular gas pressure = 22.65.
Ratio of osmotic to gas pressure = 1.053.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.01 atmosphere.
Osmotic pressure = 2.41 atmospheres.
Molecular osmotic pressure = 24.10.
Ratio of osmotic to gas pressure = 1.062.

Table III.

Original wt. normal concentration of solution, 0.1.
Rotation of original solution, 12°.55 at 20° C.
Rotation at conclusion of exp't 12°.45 at 20° C.
Loss in rotation, 0°.1 = 0.8 per cent.
Calibration units of air in manometer, 435.09.
Time of setting up cell, 4.15 P.M., Feb. 14, 1907.

Experiment No. 2.
Manometer used, No. 13.
Capillary depression, 0.02.
Cell used, I.
Resistance of membrane, 220,400.
Initial pressure, 2.16 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated
Feb. 14.											
9.00 P.M.	(5°.4)	6°.95	160.88	156.88	1.00	0.48	0.01	0.02			
Feb. 15.											
10.00 A.M.	4°.95	5°.9	153.46	150.21	1.00	0.48	0.01	0.02	2.39	2.27	0.12
1.00 P.M.	4°.60	6°.0	153.92	150.61	1.00	0.45	0.01	0.02	2.38	2.26	0.12
5.10 P.M.	4°.50	5°.9	153.51	150.26	1.00	0.48	0.01	0.02	2.39	2.26	0.13
Feb. 16.											
12.10 A.M.	5°.30	6°.6	153.47	149.84	1.00	0.48	0.01	0.02	2.39	2.27	0.12
10.30 P.M.	5°.30	6°.3	153.02	149.56	1.00	0.48	0.01	0.02	2.40	2.27	0.13
	4°.93		Displacement of manometer = 0.34 mm.						2.39		

Correction, if all loss in rotation is ascribed to inversion = 0.01 atmosphere.
Osmotic pressure = 2.39 atmospheres.
Molecular osmotic pressure = 23.90.
Molecular gas pressure = 22.66.
Ratio of osmotic to gas pressure = 1.053

Correction, if one-half the loss in rotation is ascribed to dilution = 0.01 atmosphere.
Osmotic pressure = 2.41 atmospheres.
Molecular osmotic pressure = 24.10.
Ratio of osmotic to gas pressure = 1.062

Table IV.

Original wt. normal concentration of solution, 0.2. Experiment No. 1.
Rotation of original solution, 25°.1 at 18° C. Manometer used, No. 5.
Rotation at conclusion of experiment, 24°.8 at 18°C. Capillary depression, 0.02.
Loss in rotation, 0°.3 = 1.20 per cent. Cell used, B.
Calibration units of air in manometer, 434.98. Resistance of membrane, 366,700
Time of setting up cell, 5.30 P.M., Feb. 23, 1907. Initial pressure, 3.38 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Difference between Theoretical gas pressure and found pressure.	Difference between Theoretical gas pressure and calculated.
Feb. 23.											
9.00 P.M.	(5°.1)	(6°.4)	(89.13)	(87.09)	1.02	0.58	0.04	0.02	(4.54)	(4.54)	(0.00)
Feb. 24.											
10.00 A.M.	(4°.8)	(5°.8)	(86.45)	(84.66)	1.02	0.58	0.04	0.02	(4.68)	(4.53)	(0.15)
3.30 P.M.	(4°.5)	(5°.4)	(86.54)	(84.86)	1.01	0.58	0.04	0.02	(4.68)	(4.53)	(0.15)
9.30 P.M.	4°.4	5°.5	86.59	84.88	1.00	0.58	0.04	0.02	4.69	4.53	0.16
Feb. 25.											
9.30 A.M.	5°.0	5°.9	86.36	84.53	1.00	0.58	0.04	0.02	4.71	4.54	0.17
3.00 P.M.	4°.4	5°.7	86.45	84.68	1.00	0.58	0.04	0.02	4.70	4.53	0.17
5.30 P.M.	4°.5	6°.0	86.49	84.62	1.00	0.58	0.04	0.02	4.70	4.53	0.17
	4°.58		Displacement of manometer = 0.22 mm.						4.70		

Correction, if all loss in rotation is ascribed to inversion = 0.04 atmosphere.
Osmotic pressure = 4.70 atmospheres.
Molecular osmotic pressure = 23.50.
Molecular gas pressure = 22.67.
Ratio of osmotic to gas pressure = 1.038.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.03 atmosphere.
Osmotic pressure = 4.77 atmospheres.
Molecular osmotic pressure = 23.85.
Ratio of osmotic to gas pressure = 1.053.

Table V.

Original wt. normal concentration of solution, 0.2. Experiment No. 2.
Rotation of original solution, 24°.8 at 21° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 24°.75 at 21° C. Capillary depression, 0.02.
Loss in rotation, 0°.05 = 0.2 per cent. Cell used, B.
Calibration units of air in manometer, 435.09. Resistance of membrane, 275,000.
Time of setting up cell, 4.45 P.M., March 16, 1907. Initial pressure, 4.03 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.				Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.			
March 17.											
10.30 A.M.	5°.75	6°.8	86.49	84.38	1.01	0.57	0.01	0.02	4.73	4.55	0.18
3.30 P.M.	5°.8	7°.0	86.47	84.30	1.00	0.57	0.01	0.02	4.74	4.55	0.19
March 18.											
10.00 A.M.	6°.45	7°.55	86.18	83.86	1.01	0.57	0.01	0.02	4.76	4.56	0.20
1.30 P.M.	6°.2	7°.4	86.26	83.98	1.01	0.57	0.01	0.02	4.75	4.56	0.19
	6°.05		Displacement of manometer = 0.04 mm.						4.75		

Correction, if all loss in rotation is ascribed to inversion = 0.01 atmosphere.
Osmotic pressure = 4.75 atmospheres.
Molecular osmotic pressure = 23.73.
Molecular gas pressure = 22.78.
Ratio of osmotic to gas pressure = 1.042.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.00 atmosphere.
Osmotic pressure = 4.76 atmospheres.
Molecular osmotic pressure = 23.80.
Ratio of osmotic to gas pressure = 1.044.

Table VI.

Original wt. normal concentration of solution, 0.3. Experiment No. 1.
Rotation of original solution, 36°.6 at 20°.5 C. Manometer used, No. 5.
Rotation at conclusion of exp't, 36°.3 at 20°.5 C. Capillary depression, 0.02.
Loss in rotation, 0°.3 = 0.82 per cent. Cell used, D.
Calibration units of air in manometer, 434.98. Resistance of membrane, 220,000.
Time of setting up cell, 11.45 A.M., April 2, 1907. Initial pressure, 5.98 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
April 2.											
3.00 P.M.	(4°.6)	9°.2	61.11	59.11	1.00	0.61	0.04	0.02			
5.20 P.M.	4°.45	9°.5	60.34	58.31	1.00	0.61	0.04	0.02	7.05	6.79	0.26
8.45 P.M.	4°.45	7°.9	59.94	58.25	1.00	0.61	0.04	0.02	7.06	6.79	0.27
April 3.											
9.45 A.M.	(4°.4)	5°.8	59.60	58.36	1.01	0.61	0.04	0.02	(7.03)	6.79	0.24
12.00 M.	4°.5	6°.6	59.66	58.25	1.00	0.61	0.04	0.02	7.06	6.79	0.27
2.30 P.M.	4°.6	7°.4	59.75	58.17	1.00	0.61	0.04	0.02	7.07	6.79	0.28
	4°.5		Displacement of manometer = 0.07 mm.						7.06		

Correction, if all loss in rotation is ascribed to inversion = 0.04 atmosphere.
Osmotic pressure = 7.06 atmospheres.
Molecular osmotic pressure = 23.53.
Molecular gas pressure = 22.63.
Ratio of osmotic to gas pressure = 1.040.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.03 atmosphere.
Osmotic pressure = 7.13 atmospheres.
Molecular osmotic pressure = 23.77.
Ratio of osmotic to gas pressure = 1.050.

Table VII.

Original wt. normal concentration of solution, 0.3.
Rotation of original solution, 36°.6 at 20°.5 C.
Rotation at conclusion of exp't., 36°.3 at 20°.5 C.
Loss in rotation, 0°.3 = 0.82 per cent.
Calibration units of air in manometer, 396.89.
Time of setting up cell, 12.00 M., April 2, 1907.

Experiment No. 2.
Manometer used, No. 6.
Capillary depression, 0.02.
Cell used, G.
Resistance of membrane, 138,000.
Initial pressure, 5.44 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Difference between Theoretical gas pressure and pressure found.	Difference between pressure found and calculated.
April 2.											
3.00 P.M.	(4°.6)	9°.2	55.93	54.06	1.00	0.63	0.04	0.02	(6.95)	6.79	
5.20 P.M.	4°.45	9°.5	55.58	53.71	1.00	0.63	0.04	0.02	7.00	6.79	0.21
8.45 P.M.	4°.45	7°.9	55.23	53.68	1.00	0.63	0.04	0.02	7.00	6.79	0.21
April 3.											
9.45 A.M.	(4°.4)	5°.8	54.99	53.84	1.01	0.63	0.04	0.02	(6.97)	6.79	0.18
12.00 M.	4°.5	6°.6	55.04	53.74	1.00	0.63	0.04	0.02	7.00	6.79	0.21
2.30 P.M.	4°.6	7°.4	55.19	53.73	1.00	0.63	0.04	0.02	7.00	6.79	0.21
	4°.5		Displacement of manometer = 0.07 mm.						7.00		

Correction, if all loss in rotation is ascribed to inversion = 0.04 atmosphere.
Osmotic pressure = 7.00 atmospheres.
Molecular osmotic pressure = 23.33.
Molecular gas pressure = 22.63.
Ratio of osmotic to gas pressure = 1.031.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.03 atmosphere.
Osmotic pressure = 7.07 atmospheres.
Molecular osmotic pressure = 23.57.
Ratio of osmotic to gas pressure = 1.041.

Table VIII.

Original wt. normal concentration of solution, 0.4.
Rotation of original solution, 48°.0 at 19° C.
Rotation at conclusion of exp't, 47°.6 at 19° C.
Loss in rotation, 0°.4 = 0.83 per cent.
Calibration units of air in manometer, 465.94.
Time of setting up cell, 4.45 P.M., Feb. 25, 1907.

Experiment No. 1.
Manometer used, No. 11.
Capillary depression, 0.02.
Cell used, I.
Resistance of membrane, 182,500.
Initial pressure, 8.11 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Difference between Theoretical gas pressure and pressure found and calculated.	
Feb. 25.											
9.00 P.M.	5°.1	6°.5	48.40	47.27	1.01	0.54	0.06	0.02	9.35	9.07	0.28
Feb. 26.											
10.00 A.M.	4°.4	5°.35	47.85	46.93	1.01	0.54	0.06	0.02	9.42	9.05	0.37
1.45 P.M.	4°.2	5°.6	48.07	47.10	1.01	0.54	0.06	0.02	9.38	9.04	0.34
4.15 P.M.	4°.2	5°.95	48.18	47.15	1.00	0.54	0.06	0.02	9.38	9.04	0.34
	4°.48		Displacement of manometer = 0.03 mm.						9.38		

Correction, if all loss in rotation is ascribed to inversion = 0.06 atmosphere.
Osmotic pressure = 9.38 atmospheres.
Molecular osmotic pressure = 23.46.
Molecular gas pressure = 22.63.
Ratio of osmotic to gas pressure = 1.036.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.04 atmosphere.
Osmotic pressure = 9.48 atmospheres.
Molecular osmotic pressure = 23.70.
Ratio of osmotic to gas pressure = 1.048.

Table IX.

Original wt. normal concentration of solution, 0.4.
Rotation of original solution, 48°.0 at 20° C.
Rotation at conclusion of exp't, 47°.1 at 20° C.
Loss in rotation, 0°.9 = 1.88 per cent.
Calibration units of air in manometer, 434.98.
Time of setting up cell, 5.15 P.M., March 2, 1907.

Experiment No. 2.
Manometer used, No. 5.
Capillary depression, 0.02.
Cell used, B.
Resistance of membrane, 270,000.
Initial pressure, 7.66 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 2.											
9.00 P.M.	5°.0	6°.5	45.53	44.47	0.99	0.63	0.13	0.02	9.31	9.07	0.24
March 3.											
11.30 A.M.	4°.5	5°.7	45.56	44.63	0.99	0.63	0.13	0.02	9.28	9.05	0.23
3.15 P.M.	4°.4	5°.4	45.56	44.67	0.99	0.63	0.13	0.02	9.27	9.05	0.22
7.30 P.M.	4°.3	5°.4	45.54	44.66	1.00	0.63	0.13	0.02	9.26	9.05	0.21
March 4.											
10.00 A.M.	4°.7	5°.7	45.47	44.54	1.00	0.63	0.13	0.02	9.29	9.06	0.23
1.30 P.M.	4°.4	5°.65	45.45	44.53	1.00	0.63	0.13	0.02	9.29	9.05	0.24
4.45 P.M.	4°.3	5°.8	45.49	44.54	1.00	0.63	0.13	0.02	9.29	9.05	0.24
	4°.51		Displacement of manometer = 0.15 mm.						9.28		

Correction, if all loss in rotation is ascribed to inversion = 0.13 atmosphere.
Osmotic pressure = 9.28 atmospheres.
Molecular osmotic pressure = 23.21.
Molecular gas pressure = 22.64.
Ratio of osmotic to gas pressure = 1.025.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.09 atmosphere.
Osmotic pressure = 9.50 atmospheres.
Molecular osmotic pressure = 23.75.
Ratio of osmotic to gas pressure = 1.050.

Table X.

Original wt. normal concentration of solution, 0.5.
Rotation of original solution, 58°.85 at 21° C.
Rotation at conclusion of exp't, 58°.15, at 21° C.
Loss in rotation, 0°.75 = 1.27 per cent.
Calibration units of air in manometer, 434.98.
Time of setting up cell, 4.30 P.M., March 5, 1907.

Experiment No. 1.
Manometer used, No. 5.
Capillary depression, 0.02.
Cell used, B.
Resistance of membrane, 160,000.
Initial pressure, 10.29 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 5.											
9.00 P.M.	4°.7	6°.2	36.61	35.80	0.99	0.64	0.06	0.02	11.76	11.33	0.43
March 6.											
10.00 A.M.	4°.25	5°.3	36.61	35.91	1.00	0.64	0.06	0.02	11.71	11.31	0.40
12.15 P.M.	4°.2	5°.6	36.61	35.87	1.01	0.64	0.06	0.02	11.72	11.30	0.42
3.00 P.M.	4°.2	5°.55	36.58	35.85	1.01	0.64	0.06	0.02	11.72	11.30	0.42
	4°.34		Displacement of manometer = 0.30 mm.						11.73		

Correction, if all loss in rotation is ascribed to inversion = 0.06 atmosphere.
Osmotic pressure = 11.73 atmospheres.
Molecular osmotic pressure = 23.46.
Molecular gas pressure = 22.62.
Ratio of osmotic to gas pressure = 1.037.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.08 atmosphere.
Osmotic pressure = 11.87 atmospheres.
Molecular osmotic pressure = 23.74.
Ratio of osmotic to gas pressure = 1.050.

Table XI.

Original wt. normal concentration of solution, 0.5. Experiment No. 2.
Rotation of original solution, 58°.7. at 21° C. Manometer used, No. 5.
Rotation at conclusion of exp't, 57°.95 at 21° C. Capillary depression, 0.02.
Loss in rotation, 0°.75 = 1.28 per cent. Cell used, B
Calibration units of air in manometer, 434.98. Resistance of membrane, 356,700.
Time of setting up cell, 3.45 P.M., March 14, 1907. Initial pressure, 9.77 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 14.											
8.15 P.M.	(5°.4)	6°.95	37.09	36.17	1.00	0.64	0.11	0.02			
March 15.											
10.00 A.M.	5°.5	7°.0	36.53	35.62	1.01	0.64	0.11	0.02	11.75	11.36	0.39
11.00 A.M.	5°.4	6°.4	36.53	35.69	1.01	0.64	0.11	0.02	11.73	11.36	0.37
2.15 P.M.	5°.0	6°.4	36.50	35.66	1.01	0.64	0.11	0.02	11.74	11.34	0.40
3.45 P.M.	5°.0	6°.5	36.50	35.70	1.01	0.64	0.11	0.02	11.72	11.34	0.38
	5°.23		Displacement of manometer = 0.17 mm.						11.74		

Correction, if all loss in rotation is ascribed to inversion = 0.11 atmosphere.
Osmotic pressure = 11.74 atmospheres.
Molecular osmotic pressure = 23.47
Molecular gas pressure = 22.70.
Ratio of osmotic to gas pressure = 1.034.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.08 atmosphere.
Osmotic pressure = 11.93 atmospheres.
Molecular osmotic pressure = 23.86.
Ratio of osmotic to gas pressure = 1.051.

Table XII.

Original wt. normal concentration of solution, 0.6. Experiment No. 1.
Rotation of original solution 69°.55 at 19° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 68°.5 at 19° C. Capillary depression, 0.02.
Loss in rotation, 0.05 = 1.51 per cent. Cell used, I.
Calibration units of air in manometer, 435.09. Resistance of membrane, 156,900.
Time of setting up cell, 4.00 P.M., Feb. 21, 1907. Initial pressure, 12.55 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
Feb. 21.											
9.00 P.M.	(5°.1)	6°.8	30.47	29.73	1.00	0.64	0.17	0.02			
Feb. 22.											
9.45 A.M.	4°.7	6°.5	30.17	29.47	1.01	0.64	0.17	0.02	14.26	13.59	0.67
3.00 P.M.	5°.2	6°.7	30.22	29.49	1.01	0.64	0.17	0.02	14.23	13.61	0.62
4.00 P.M.	5°.2	6°.7	30.25	29.52	1.01	0.64	0.17	0.02	14.22	13.61	0.61
	5°.03		Displacement of manometer = 0.26 mm.						14.24		

Correction, if all loss in rotation is ascribed to inversion = 0.17 atmosphere.
Osmotic pressure = 14.24 atmospheres.
Molecular osmotic pressure = 23.73.
Molecular gas pressure = 22.68.
Ratio of osmotic to gas pressure = 1.047.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.11 atmosphere.
Osmotic pressure = 14.52 atmospheres.
Molecular osmotic pressure = 24.20.
Ratio of osmotic to gas pressure = 1.068.

Table XIII.

Original wt. normal concentration of solution, 0.6. Experiment No. 2.
Rotation of original solution, 69°.25 at 19° C. Manometer used, No. 11.
Rotation at conclusion of exp't, 68°.55 at 19° C. Capillary depression, 0.02.
Loss in rotation, 0°.7 = 1.01 per cent. Cell used, I.
Calibration units of air in manometer, 465.94. Resistance of membrane, 185,500.
Time of setting up cell, 5.00 P.M., March 16, 1907. Initial pressure, 11.80 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Difference between Theoretical gas pressure.	Difference between found and calculated.
March 17.											
10.30 A.M.	5°.75	6°.8	32.13	31.35	1.01	0.56	0.10	0.02	14.33	13.64	0.69
3.30 P.M.	5°.8	7°.0	32.16	31.35	1.00	0.56	0.10	0.02	14.34	13.64	0.70
March 18.											
10.00 A.M.	6°.45	7°.55	32.12	31.25	1.01	0.56	0.10	0.02	14.38	13.68	0.70
1.30 P.M.	6°.2	7°.4	32.14	31.29	1.01	0.56	0.10	0.02	14.36	13.66	0.70
	6°.05		Displacement of manometer = 0.05 mm.						14.35		

Correction, if all loss in rotation is ascribed to inversion = 0.10 atmosphere.
Osmotic pressure = 14.35 atmospheres.
Molecular osmotic pressure = 23.92.
Molecular gas pressure = 22.76.
Ratio of osmotic to gas pressure = 1.051.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.07 atmosphere.
Osmotic pressure = 14.52 atmospheres.
Molecular osmotic pressure = 24.20.
Ratio of osmotic to gas pressure = 1.063

Table XIV.

Original wt. normal concentration of solution, 0.7. Experiment No. 1.
Rotation of original solution, 79°.3 at 19° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 78°.3 at 19° C. Capillary depression, 0.02.
Loss in rotation, 1°.0 = 1.26 per cent. Cell used, I.
Calibration units of air in manometer, 435.09. Resistance of membrane, 184,000.
Time of setting up cell, 5.00 P.M., Feb. 16, 1907. Initial pressure, 14.60 atmospheres.

	Temperature.		Volume of ar in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
Feb. 16.											
9.00 P.M.	(5°.55)	7°.1	26.30	25.63	1.00	0.64	0.15	0.02			
Feb. 17.											
10.30 A.M.	(5°.05)	6°.05	26.29	25.72	1.00	0.64	0.15	0.02			
3.15 P.M.	(4°.85)	6°.0	26.18	25.62	1.00	0.64	0.15	0.02			
Feb. 18.											
11.00 A.M.	4°.5	5°.13	25.95	25.47	1.00	0.64	0.15	0.02	16.59	15.84	0.75
3.35 P.M.	4°.2	5°.28	25.99	25.50	1.00	0.64	0.15	0.02	16.57	15.83	0.74
	4°.35		Displacement of manometer = 0.23 mm.						16.58		

Correction, if all loss in rotation is ascribed to inversion = 0.15 atmosphere.
Osmotic pressure = 16.58 atmospheres.
Molecular osmotic pressure = 23.69.
Molecular gas pressure = 22.62.
Ratio of osmotic to gas pressure = 1.047.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.11 atmosphere.
Osmotic pressure = 16.84 atmospheres.
Molecular osmotic pressure = 24.06.
Ratio of osmotic to gas pressure = 1.063.

Table XV.

Original wt. normal concentration of solution, 0.7. Experiment No. 2.
Rotation of original solution, 79°.4 at 21° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 78°.0 at 21° C. Capillary depression, 0.02.
Loss in rotation, 1°.4 = 1.76 per cent. Cell used, B.
Calibration units of air in manometer, 435.09. Resistance of membrane, 260,000.
Time of setting up cell, 6.00 P.M., March 9, 1907. Initial pressure, 13.97 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 10.											
12.00 M.	(4°.65)	5°.7	25.97	25.44	1.00	0.65	0.21	0.02			
4.00 P.M.	(4°.55)	5°.45	25.99	26.07	1.00	0.65	0.21	0.02			
March 11.											
10.00 A.M.	4°.75	5°.9	25.83	25.28	1.01	0.65	0.21	0.02	16.66	15.86	0.80
12.00 M.	4°.5	5°.6	25.82	25.30	1.01	0.65	0.21	0.02	16.65	15.84	0.81
3.00 P.M.	4°.4	5°.8	25.89	25.35	1.01	0.65	0.21	0.02	16.61	15.84	0.77
	4°.55		Displacement of manometer = 0.49 mm.						16.64		

Correction, if all loss in rotation is ascribed to inversion = 0.21 atmosphere.
Osmotic pressure = 16.64 atmospheres.
Molecular osmotic pressure = 23.77.
Molecular gas pressure = 22.64.
Ratio of osmotic to gas pressure = 1.050.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.15 atmosphere.
Osmotic pressure = 17.00 atmospheres.
Molecular osmotic pressure = 24.29.
Ratio of osmotic to gas pressure = 1.073.

Table XVI.

Original wt. normal concentration of solution, 0.8. Experiment No. 1.
Rotation of original solution, 89°.1 at 19° C. Manometer used, No. 5.
Rotation at conclusion of exp't, 87°.55 at 19° C. Capillary depression, 0.02.
Loss in rotation, 1°.55 = 1.74 per cent. Cell used, I.
Calibration units of air in manometer, 434.98. Resistance of membrane, 157,400.
Time of setting up cell, 4.00 P.M., Feb. 27, 1907. Initial pressure, 15.80 atmospheres.

Time.	Temperature.		Volume of air in manometer.		Corrections.				Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.			
Feb. 27.											
9.00 P.M.	4°.9	6°.3	22.62	22.11	1.01	0.66	0.24	0.02	19.10	18.13	0.97
Feb. 28.											
10.30 A.M.	4°.6	5°.55	22.66	22.21	1.01	0.66	0.24	0.02	19.02	18.11	0.91
12.30 P.M.	4°.25	5°.3	22.65	22.22	1.01	0.66	0.24	0.02	19.01	18.09	0.92
4.00 P.M.	4°.15	5°.5	22.71	22.26	1.01	0.66	0.24	0.02	18.97	18.08	0.89
	4°.48		Displacement of manometer = 0.32 mm.						19.03		

Correction, if all loss in rotation is ascribed to inversion = 0.24 atmosphere.
Osmotic pressure = 19.03 atmospheres.
Molecular osmotic pressure = 23.78.
Molecular gas pressure = 22.63.
Ratio of osmotic to gas pressure = 1.051.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.17 atmosphere.
Osmotic pressure = 19.44 atmospheres.
Molecular osmotic pressure = 24.30.
Ratio of osmotic to gas pressure = 1.074.

Table XVII.

Original wt. normal concentration of solution, 0.8. Experiment No. 2.
Rotation of original solution, 89°.1 at 21° C. Manometer used, No. 11.
Rotation at conclusion of exp't, 87°.7 at 21° C. Capillary depression, 0.02.
Loss in rotation, 1°.4 = 1.57 per cent. Cell used, I.
Calibration units of air in manometer, 465.94. Resistance of membrane, 87,000.
Time of setting up cell, 4.15 P.M., March 1, 1907. Initial pressure, 17.23 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 1.											
9.45 P.M	4°.4	5°.8	24.06	23.56	1.00	0.57	0.17	0.02	19.20	18.10	1.10
March 2.											
9.00 A.M.	4°.25	5°.5	24.08	23.60	0.99	0.57	0.17	0.02	19.17	18.09	1.08
12.15 P.M.	4°.3	5°.6	24.11	23.62	0.99	0.57	0.17	0.02	19.15	18.09	1.06
3.00 P.M.	4°.3	5°.8	24.14	23.64	0.99	0.57	0.17	0.02	19.14	18.09	1.05
5.15 P.M.	4°.4	6°.05	24.11	23.59	0.99	0.57	0.17	0.02	19.18	18.10	1.08
	4°.33		Displacement of manometer = 0.19 mm.						19.17		

Correction, if all loss in rotation is ascribed to inversion = 0.17 atmosphere.
Osmotic pressure = 19.17 atmospheres.
Molecular osmotic pressure = 23.96.
Molecular gas pressure = 22.62.
Ratio of osmotic to gas pressure = 1.060.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.15 atmosphere.
Osmotic pressure = 19.49 atmospheres.
Molecular osmotic pressure = 24.36.
Ratio of osmotic to gas pressure = 1.077.

Table XVIII.

Original wt. normal concentration of solution, 0.9. Experiment No. 1.
Rotation of original solution, 98°.4 at 20° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 96°.8 at 20° C. Capillary depression, 0.02.
Loss in rotation, 1°.6 = 1.63 per cent. Cell used, I.
Calibration units of air in manometer, 435.09. Resistance of membrane, 209,000.
Time of setting up cell, 4.00 P.M., Feb. 19, 1907. Initial pressure

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
Feb. 19.											
9.00 P.M.	(4°.5)	5°.8	19.96	19.54	0.99	0.66	0.25	0.02			
Feb. 20.											
10.00 A.M.	4°.4	5°.5	19.82	19.43	0.99	0.66	0.25	0.02	21.84	20.37	1.47
2.45 P.M.	4°.3	5°.5	19.87	19.48	0.99	0.66	0.25	0.02	21.79	20.36	1.43
4.45 P.M.	4°.3	5°.7	19.83	19.42	0.99	0.66	0.25	0.02	21.84	20.36	1.48
	4°.33		Displacement of manometer = 0.19 mm.						21.82		

Correction, if all loss in rotation is ascribed to inversion = 0.25 atmosphere.
Osmotic pressure = 21.82 atmospheres.
Molecular osmotic pressure = 24.25.
Molecular gas pressure = 22.63.
Ratio of osmotic to gas pressure = 1.072.

Correction if one-half the loss in rotation is ascribed to dilution = 0.18 atmosphere.
Osmotic pressure = 22.25 atmospheres.
Molecular osmotic pressure = 24.72.
Ratio of osmotic to gas pressure = 1.093.

Table XIX.

Original wt. normal concentration of solution, 0.9. Experiment No. 2.
Rotation of original solution, 98°.25 at 21° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 96°.6 at 21° C. Capillary depression, 0.02.
Loss in rotation, 1°.65 = 1.68 per cent. Cell used, I.
Calibration units of air in manometer, 435.09. Resistance of membrane, 108,800.
Time of setting up cell, 4.00 P.M., March 14, 1907. Initial pressure, 18.21 atmospheres.

Time. March 14.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Difference between Theoretical gas pressure.	Difference between pressure found and calculated.
8.15 P.M. March 15.	(5°.4)	6°.95	19.87	19.38	1.00	0.66	0.26	0.02			
10.00 A.M.	5°.5	7°.0	19.74	19.25	1.00	0.66	0.26	0.02	22.02	20.44	1.58
11.00 A.M.	5°.4	6°.4	19.74	19.29	1.00	0.66	0.26	0.02	21.97	20.44	1.53
2.15 P.M.	5°.0	6°.4	19.79	19.34	1.00	0.66	0.26	0.02	21.91	20.40	1.51
3.45 P.M.	5°.0	6°.5	19.78	19.32	1.00	0.66	0.26	0.02	21.93	20.40	1.53
	5°.23		Displacement of manometer = 0.4 mm.						21.96		

Correction, if all loss in rotation is ascribed to inversion = 0.26 atmosphere.
Osmotic pressure = 21.96 atmospheres.
Molecular osmotic pressure = 24.40.
Molecular gas pressure = 22.69.
Ratio of osmotic to gas pressure = 1.075.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.19 atmosphere.
Osmotic pressure = 22.41 atmospheres.
Molecular osmotic pressure = 24.90.
Ratio of osmotic to gas pressure = 1.097.

Table XX.

Original wt. normal concentration of solution, 1.0. Experiment No. 1.
Rotation of original solution, 107°.4 at 19° C. Manometer used, No. 11.
Rotation at conclusion of exp't, 105°.7 at 19° C. Capillary depression, 0.02.
Loss in rotation 1°.7 = 1.58 per cent. Cell used, I.
Calibration units of air in manometer, 465.94. Resistance of membrane, 135,000.
Time of setting up cell, 5.00 P.M., March 4, 1907. Initial pressure, 21.39 atmospheres.

Time.	Temperature. Solution.	Temperature. Air in manometer.	Volume of air in manometer. Uncorrected.	Volume of air in manometer. Corrected.	Corrections. Atmospheric pressure.	Corrections. Liquids in manometer.	Corrections. Inversion.	Corrections. Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 4.											
10.00 P.M.	5°.0	6°.35	19.13	18.69	1.01	0.58	0.27	0.02	24.24	22.67	1.57
March 5.											
9.00 A.M.	4°.7	5°.75	19.05	18.66	1.00	0.58	0.27	0.02	24.31	22.65	1.66
12.30 P.M.	4°.4	5°.75	19.11	18.72	1.00	0.58	0.27	0.02	24.23	22.63	1.60
3.45 P.M.	4°.3	5°.8	19.13	18.73	1.00	0.58	0.27	0.02	24.21	22.62	1.59
	4°.6		Displacement of manometer = 0.41 mm.						24.25		

Correction, if all loss in rotation is ascribed to inversion = 0.27 atmosphere.
Osmotic pressure = 24.25 atmospheres.
Molecular osmotic pressure = 24.25.
Molecular gas pressure = 22.64.
Ratio of osmotic to gas pressure = 1.071.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.20 atmosphere..
Osmotic pressure = 24.72 atmospheres.
Molecular osmotic pressure = 24.72.
Ratio of osmotic to gas pressure = 1.092.

Table XXI.

Original wt. normal concentration of solution, 1.0. Experiment No. 2.
Rotation of original solution, 107°.5 at 19° C. Manometer used, No. 13.
Rotation at conclusion of exp't, 105°.4 at 19° C. Capillary depression, 0.02.
Loss in rotation, 2°.1 = 1.95 per cent. Cell used, I.
Calibration units of air in manometer, 435.09. Resistance of membrane, 107,500.
Time of setting up cell, 4.30 P.M., March 6, 1907. Initial pressure, 20.94 atmospheres.

	Temperature.		Volume of air in manometer.		Corrections.						
Time.	Solution.	Air in manometer.	Uncorrected.	Corrected.	Atmospheric pressure.	Liquids in manometer.	Inversion.	Capillary depression.	Osmotic pressure corrected.	Theoretical gas pressure.	Difference between pressure found and calculated.
March 6.											
10.00 P.M.	4°.55	5°.95	17.85	17.47	1.01	0.66	0.33	0.02	24.25	22.64	1.61
March 7.											
10.00 A.M.	(4°.2)	5°.3	17.94	17.60	1.01	0.66	0.33	0.02	(24.06)	22.61	1.45
12.15 P.M.	4°.2	5°.4	17.88	17.53	1.01	0.66	0.33	0.02	24.16	22.61	1.55
3.30 P.M.	4°.2	5°.55	17.87	17.51	1.01	0.66	0.33	0.02	24.18	22.61	1.57
	4°.32		Displacement of manometer = 0.59 mm.						24.20		

Correction, if all loss in rotation is ascribed to inversion = 0.33 atmosphere.
Osmotic pressure = 24.20 atmospheres.
Molecular osmotic pressure = 24.20.
Molecular gas pressure = 22.62.
Ratio of osmotic to gas pressure = 1.070.

Correction, if one-half the loss in rotation is ascribed to dilution = 0.24 atmosphere.
Osmotic pressure = 24.77 atmospheres.
Molecular osmotic pressure = 24.77.
Ratio of osmotic to gas pressure = 1.095.

Table XXII.—Cane Sugar.

Series IV.

Weight normal concentration.	Number of experiments.	Displacement of manometer. mm.	Loss in rotation.		Corrections.		Limit of uncertainty. Atmosphere.
			1. Degrees.	2. Percentage.	1. If all loss in rotation is ascribed to inversion. Atmosphere.	2. If ½ the loss in rotation is ascribed to dilution. Atmosphere.	
1.	2.	3.	4.	5.	6.	7.	8.
0.1	1	0.40	0°.1	0.80	0.01	0.01	0.02
"	2	0.34	0°.1	0.80	0.01	0.01	0.02
0.2	1	0.22	0°.3	1.20	0.04	0.03	0.07
"	2	0.04	0°.05	0.20	0.01	0.00	0.01
0.3	1	0.07	0°.3	0.82	0.04	0.03	0.07
"	2	0.07	0°.3	0.82	0.04	0.03	0.07
0.4	1	0.03	0°.4	0.83	0.06	0.04	0.10
"	2	0.15	0°.9	1.88	0.13	0.09	0.22
0.5	1	0.30	0°.75	1.27	0.06	0.08	0.14
"	2	0.17	0°.75	1.28	0.11	0.08	0.19
0.6	1	0.26	1°.05	1.51	0.17	0.11	0.28
"	2	0.05	0°.7	1.01	0.10	0.07	0.17
0.7	1	0.23	1°.0	1.26	0.15	0.11	0.26
"	2	0.49	1°.4	1.76	0.21	0.15	0.36
0.8	1	0.32	1°.55	1.74	0.24	0.17	0.41
"	2	0.19	1°.4	1.57	0.17	0.15	0.32
0.9	1	0.19	1°.6	1.63	0.25	0.18	0.43
"	2	0.40	1°.65	1.68	0.26	0.19	0.45
1.0	1	0.41	1°.7	1.58	0.27	0.20	0.47
"	2	0.59	2°.1	1.95	0.33	0.24	0.57

Mean = 1.28 per cent.

Table XXIII.—Cane Sugar.

Series IV.

Weight-normal concentration.	Number of experiment.	Temperature of solution.	Osmotic pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If ½ the loss in rotation is ascribed to dilution.	Calculated gas pressure at same temperature.
0.1	1	4°.84	2.40	2.39	2.41	2.27
"	2	4°.93	2.40	2.39	2.41	2.27
0.2	1	4°.58	4.74	4.70	4.77	4.53
"	2	6°.05	4.76	4.75	4.76	4.56
0.3	1	4°.50	7.10	7.06	7.13	6.79
"	2	4°.50	7.04	7.00	7.07	6.79
0.4	1	4°.48	9.44	9.38	9.48	9.05
"	2	4°.51	9.41	9.28	9.50	9.05
0.5	1	4°.34	11.79	11.73	11.87	11.31
"	2	5°.23	11.85	11.74	11.93	11.35
0.6	1	5°.03	14.41	14.24	14.52	13.60
"	2	6°.05	14.45	14.35	14.52	13.66
0.7	1	4°.35	16.73	16.58	16.84	15.84
"	2	4°.55	16.85	16.64	17.00	15.85
0.8	1	4°.48	19.27	19.03	19.44	18.10
"	2	4°.33	19.34	19.17	19.49	18.09
0.9	1	4°.33	22.07	21.82	22.25	20.36
"	2	5°.23	22.22	21.96	22.41	20.42
1.0	1	4°.60	24.52	24.25	24.72	22.64
"	2	4°.32	24.53	24.20	24.77	22.62

Table XXIV.—Cane Sugar.

Series IV.

Weight-normal concentration.	Temperature of solution.	Osmotic pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If ½ the loss in rotation is ascribed to dilution.	Calculated gas pressure for same temperature.
0.1	4°.89	2.40	2.39	2.41	2.27
0.2	5°.32	4.75	4.73	4.77	4.55
0.3	4°.50	7.07	7.03	7.10	6.79
0.4	4°.50	9.43	9.33	9.49	9.05
0.5	4°.79	11.82	11.74	11.90	11.33
0.6	5°.54	14.43	14.30	14.32	13.63
0.7	4°.45	16.79	16.61	16.92	15.85
0.8	4°.41	19.31	19.10	19.47	18.10
0.9	4°.78	22.15	21.89	22.33	20.39
1.0	4°.46	24.53	24.23	24.75	22.63

Table XXV.—Cane Sugar.

Series IV.

Weight-normal concentration.	Number of experiment.	Temperature of solution.	Molecular osmotic pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If 1/2 the loss in rotation is ascribed to dilution.	Molecular gas pressure.
0.1	1	4°.84	24.00	23.88	24.10	22.65
"	2	4°.93	24.00	23.90	24.10	22.66
0.2	1	4°.58	23.70	23.50	23.85	22.67
"	2	6°.05	23.80	23.73	23.80	22.78
0.3	1	4°.50	23.67	23.53	23.77	22.63
"	2	4°.50	23.47	23.33	23.57	22.63
0.4	1	4°.48	23.60	23.46	23.70	22.63
"	2	4°.51	23.53	23.21	23.75	22.64
0.5	1	4°.34	23.58	23.46	23.74	22.62
"	2	5°.23	23.70	23.47	23.86	22.70
0.6	1	5°.03	24.01	23.73	24.20	22.68
"	2	6°.05	24.08	23.92	24.20	22.76
0.7	1	4°.35	23.90	23.69	24.06	22.62
"	2	4°.55	24.07	23.77	24.29	22.64
0.8	1	4°.48	24.09	23.78	24.30	22.63
"	2	4°.33	24.18	23.96	24.36	22.62
0.9	1	4°.33	24.52	24.25	24.72	22.63
"	2	5°.23	24.69	24.40	24.90	22.69
1.0	1	4°.60	24.52	24.25	24.72	22.64
"	2	4°.32	24.53	24.20	24.77	22.62

Table XXVI.—Cane Sugar.

Series IV.

Weight-normal concentration.	Temperature of solution.	Molecular osmotic pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If 1/2 the loss in rotation is ascribed to dilution.	Molecular gas pressure.
0.1	4°.89	24.00	23.89	24.10	22.66
0.2	5°.32	23.75	23.62	23.83	22.73
0.3	4°.50	23.57	23.43	23.67	22.63
0.4	4°.50	23.57	23.34	23.73	22.64
0.5	4°.79	23.64	23.47	23.80	22.66
0.6	5°.54	24.05	23.83	24.20	22.72
0.7	4°.45	23.99	23.73	24.18	22.63
0.8	4°.41	24.14	23.87	24.33	22.63
0.9	4°.78	24.61	24.33	24.81	22.66
1.0	4°.46	24.53	24.23	24.75	22.63

Table XXVII.—Cane Sugar.

Series IV.

Weight-normal concentration.	Number of experiment.	Temperature of solution.	Ratio of osmotic to gas pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If 1/2 the loss in rotation is ascribed to dilution.
0.1	1	4°.84	1.057	1.053	1.062
"	2	4°.93	1.057	1.053	1.062
0.2	1	4°.58	1.046	1.038	1.053
"	2	6°.05	1.044	1.042	1.044
0.3	1	4°.50	1.046	1.040	1.050
"	2	4°.50	1.037	1.031	1.041
0.4	1	4°.48	1.043	1.036	1.048
"	2	4°.51	1.040	1.025	1.050
0.5	1	4°.34	1.042	1.037	1.050
"	2	5°.23	1.044	1.034	1.051
0.6	1	5°.03	1.060	1.047	1.068
"	2	6°.05	1.058	1.051	1.063
0.7	1	4°.35	1.056	1.047	1.063
"	2	4°.55	1.063	1.050	1.073
0.8	1	4°.48	1.065	1.051	1.074
"	2	4°.33	1.069	1.060	1.077
0.9	1	4°.33	1.084	1.072	1.093
"	2	5°.23	1.088	1.075	1.097
1.0	1	4°.60	1.083	1.071	1.092
"	2	4°.32	1.084	1.070	1.095

Table XXVIII.—Cane Sugar.

Series IV.

Weight-normal concentration.	Temperature of solution.	Ratio of osmotic to gas pressure. 1. Observed (uncorrected for loss in rotation).	2. If all loss in rotation is ascribed to inversion.	3. If $^1/_2$ the loss in rotation is ascribed to dilution.
0.1	4°.89	1.057	1.053	1.062
0.2	5°.32	1.045	1.040	1.049
0.3	4°.50	1.042	1.036	1.046
0.4	4°.50	1.042	1.031	1.049
0.5	4°.79	1.043	1.036	1.051
0.6	5°.54	1.059	1.049	1.066
0.7	4°.45	1.060	1.049	1.068
0.8	4°.41	1.067	1.056	1.076
0.9	4°.78	1.086	1.074	1.095
1.0	4°.46	1.084	1.071	1.094

Table XXIX.—Cane Sugar.

Weight-normal concentration.		Series I.[1]	Series II.	Series III.	Series IV.
0.1	Temperature	18°.46	24°.14	0°.24	4°.89
	Osmotic pressure	2 .40	2 .60 (?)	2 .44	2 .41
	Molecular osmotic pressure	24 .00	26 .00	24 .40	24 .10
	Molecular gas pressure	24 .00	24 .20	22 .30	22 .66
	Ratio of osmotic to gas pressure	1 .000	1 .074	1 .092	1 .062
0.2	Temperature	20°.75	21°.43	0°.26	5°.32
	Osmotic pressure	4 .74	4 .88	4 .80	4 .77
	Molecular osmotic pressure	23 .70	24 .40	24 .00	23 .83
	Molecular gas pressure	24 .20	24 .00	22 .30	22 .73
	Ratio of osmotic to gas pressure	0 .979	1 .017	1 .075	1 .049
0.3	Temperature	18°.47	20°.73	0°.22	4°.50
	Osmotic pressure	7 .23	7 .36	7 .16	7 .10
	Molecular osmotic pressure	24 .10	24 .53	23 .87	23 .67
	Molecular gas pressure	24 .00	23 .97	22 .30	22 .63
	Ratio of osmotic to gas pressure	1 .000	1 .024	1 .071	1 .046
0.4	Temperature	19°.91	21°.89	0°.24	4°.50
	Osmotic pressure	9 .62	9 .85	9 .40	9 .49
	Molecular osmotic pressure	24 .05	24 .63	23 .50	23 .73
	Molecular gas pressure	24 .13	24 .05	22 .30	22 .64
	Ratio of osmotic to gas pressure	0 .997	1 .024	1 .054	1 .049

[1] The calculations under Series I. were based on H = 1.008, and those under II., III. and IV. on H = 1.000. This will explain certain apparent slight inconsistencies in molecular gas pressures.

Table XXIX. (Continued).

Weight-normal concentration.		Series I.	Series II.	Series III.	Series IV.
0.5	Temperature	20°.58	23°.15	0°.21	4°.79
	Osmotic pressure	12 .09	12 .50 (?)	11 .85	11 .90
	Molecular osmotic pressure	24 .18	25 .00	23 .70	23 .80
	Molecular gas pressure	24 .18	24 .16	22 .28	22 .66
	Ratio of osmotic to gas pressure	1 .000	1 .035	1 .064	1 .051
0.6	Temperature	22°.94	24°.23	0°.22	5°.54
	Osmotic pressure	14 .41	15 .21 (?)	14 .25	14 .52
	Molecular osmotic pressure	24 .02	25 .35	23 .75	24 .20
	Molecular gas pressure	24 .38	24 .25	22 .28	22 .72
	Ratio of osmotic to gas pressure	0 .985	1 .045	1 .066	1 .066
0.7	Temperature	22°.38	23°.85	0°.21	4°.45
	Osmotic pressure	16 .91	17 .63 (?)	16 .81	16 .92
	Molecular osmotic pressure	24 .16	25 .19	24 .01	24 .18
	Molecular gas pressure	24 .33	24 .19	22 .29	22 .63
	Ratio of osmotic to gas pressure	0 .993	1 .041	1 .078	1 .068
0.8	Temperature	18°.73	23°.64	0°.22	4°.41
	Osmotic pressure	19 .43	20 .09	19 .33	19 .47
	Molecular osmotic pressure	24 .29	25 .11	24 .16	24 .33
	Molecular gas pressure	24 .05	24 .20	22 .29	22 .63
	Ratio of osmotic to gas pressure	1 .010	1 .038	1 .085	1 .076

Table XXIX. (Continued).

Weight-normal concentration.		Series I.	Series II.	Series III.	Series IV.
0.9	Temperature	19°.84	24°.78	0°.27	4°.78
	Osmotic pressure	21 .84	22 .58	22 .13	22 .33
	Molecular osmotic pressure	24 .27	25 .09	24 .59	24 .81
	Molecular gas pressure	24 .12	24 .29	22 .29	22 .66
	Ratio of osmotic to gas pressure	1 .006	1 .033	1 .103	1 .095
1.0	Temperature	22°.45	24°.07	0°.25	4°.46
	Osmotic pressure	24 .52	24 .84	24 .78	24 .75
	Molecular osmotic pressure	24 .52	24 .84	24 .78	24 .75
	Molecular gas pressure	24 .34	24 .24	22 .28	22 .63
	Ratio of osmotic to gas pressure	1 .009	1 .025	1 .112	1 .094

Summary of Results.

The tables showing the results of the experiments require some explanation. Tables II. to XXI. contain the record of the individual measurements. These tables contain, in a condensed form, all the important data of each experiment and show the osmotic pressure in atmospheres. The methods of determining the corrections for capillary depression and for liquids in the manometer have been discussed in a former paper.[1] The theoretical gas pressure has been calculated in accordance with the rule stated in the introduction to this paper. In the experiments recorded in Tables VI. and VII., the temperature was maintained by means of melting ice. In all other measurements, the temperature of the bath was regulated by running water alone.

Table XXII. shows the loss in rotation and the corresponding correction for each experiment. Column 8 of this table gives the limit of uncertainty of each experiment in atmospheres. Since the correction for inversion is subtracted from the observed pressure while that for one-half dilution is added, the limit of uncertainty amounts to the sum of these two corrections. But since it has been shown that if all loss in rotation is ascribed to inversion, the correction is almost certainly too large, it is evident that the limit of uncertainty is really less than appears from the figures in column 8.

Table XXIII. shows the mean results in atmospheres for each determination. In this table, the pressures have been calculated in three ways: namely, (1) without correction for loss in rotation, (2) ascribing all loss to inversion, and (3), ascribing one-half the loss to dilution. In the last column the calculated gas pressure at the temperature of the experiment is given. Table XXIV. gives in the same way the mean results for each concentration as calculated from Table XXIII.

The extent to which the different methods of correcting for loss in rotation influence the estimated osmotic pressure is shown here. A comparison with the calculated gas pressures, given in the last column, shows that whatever method

[1] Amer. Chem. Jour., **36**, 45, 46.

of correction is employed, the osmotic pressures are all considerably higher than the theoretical.

Tables XXV. and XXVI. show the molecular pressures in atmospheres. If we omit the pressures of the 0.1 and 0.2 normal solutions, it is evident that there is a slight rise in molecular pressure with rise in concentration and that the pressure is not exactly proportional to the concentration.

In Tables XXVII. and XXVIII. the ratios of the osmotic to the calculated gas pressures are summed up. If the osmotic pressure of cane sugar solutions at 4°.0 conformed to the rule given at the beginning, the ratio of the osmotic pressure, corrected for one-half dilution, to the calculated gas pressure should be close to unity, provided this method of correcting for loss in rotation is most accurate.

Table XXIX. has been introduced for the purpose of comparing the results of the four series of cane sugar measurements which have been made in this laboratory up to the present time.[1] It will be seen that in Series I. the molecular gas pressure is always somewhat higher than in Series II., although the temperature of the experiment in the latter series is higher than in the former. This apparent discrepancy is due to the fact that the solutions measured in Series I. were made up on the basis of O = 16, while in all the other series the basis was H = 1.00. The osmotic pressures in Series I. are uncorrected for loss in rotation, while in the other series one-half the loss in rotation is ascribed to dilution and the results corrected accordingly. Series I. is, therefore, not strictly comparable with the other three series.

It is evident that at 4°, cane sugar in solution exerts an osmotic pressure very little higher than at 0°, and that its divergence from the calculated gas pressure is almost as great as at the lower temperature. That is to say, if a temperature of minimum osmotic pressure exists betwen 0° and 20°, this minimum does not show itself between 4° and 5°. On the other hand, a comparison of the cane sugar measurements at 20° with those at 0° and at 4° shows them to be so strik-

[1] Am Chem. Jour., **34**, 40; **36**, 55; **37**, 428.

ingly close together that there would appear to be some ground for suspecting that osmotic pressure has little or no temperature coefficient. So far as we know at present, however, it may well be that the abnormalities observed at low temperatures gradually disappear with increasing temperatures and that finally a temperature may be reached at which the osmotic pressures agree with the gas pressures. In other words, it is quite possible that the temperature coefficient of osmotic pressure is as large as is to be expected by analogy with the gas laws, but that, owing to changes, not now understood, which occur in the solution, the effect of rise in temperature is counterbalanced and abnormalities make their appearance.

BIOGRAPHY.

Paul Brown Dunbar was born in Lebanon, Pennsylvania, May 29, 1882. Since 1894, his home has been in Baltimore, Maryland. He graduated from Pennsylvania College, Gettysburg, in 1904, with the degree of Bachelor of Science. In the fall of 1904, he entered the Johns Hopkins University as a graduate student in Chemistry, with Physical Chemistry and Physics as subordinate subjects.